USE OF HIGH PERFORMANCE STEEL IN TEXAS BRIDGES

Submission Date: July 31, 2002
Word Count: 2529

David P. Hohmann, P.E.

Director, Bridge Design Branch

Bridge Division

Texas Department of Transportation

125 E. 11th Street

Austin, TX 78701

Phone (512) 416-2210

Fax (512) 416-2557

Dhohman@dot.state.tx.us

John M. Holt, P.E.

Senior Design Engineer

Bridge Division

Texas Department of Transportation

125 E. 11th Street

Austin, TX 78701

Phone (512) 416-2210

Fax (512) 416-2557

Jholt@dot.state.tx..us

ABSTRACT

Like many other bridge owners, the Texas Department of Transportation (TxDOT) is successfully implementing High Performance Steel in its bridges. Most steel bridges built by TxDOT have span lengths less than 300 feet and use plate girders or trapezoidal box girders. For these bridges, TxDOT has been able to capitalize on the improved strength and weathering performance that HPS offers. All applications of HPS by TxDOT have been with hybrid girders. A few examples of steel bridges designed by TxDOT, demonstrating how HPS was used, are presented. In the future, it is expected that HPS use by TxDOT and other bridge owners will become commonplace.

ADVANTAGES PROVIDED BY HIGH PERFORMANCE STEEL

High Performance Steels (HPS)—A709 Grades HPS70W and HPS50W—possess a number of properties that make them attractive bridge materials. Compared to steels commonly used for bridge construction—A709 Grades 36, 50, and 50W—HPS possesses improved weldability, toughness, weathering performance, and in the case of Grade HPS70W, higher strength.

- *Weldability*—Weldability affects fabrication costs. Steels with better weldability have lower fabrication costs.
- *Toughness*—Toughness, or resistance against brittle fracture, is especially important in a bridge steel where brittle fracture could be costly in expense and potential loss of life.
- *Weathering*—Weathering steels have a clear cost advantage over their counterparts requiring paint for corrosion protection. Bridge steel possessing improved weathering properties such that it could be used in harsh environments is attractive to the bridge engineering community.
- *Strength*—Steel with higher strength often requires less material to satisfy load demands and can provide additional cost benefits.

In Texas' urban areas, span length requirements for grade separation bridges and flyover ramps in interchanges are increasing. Shallow superstructure depths for these situations often provide immense cost savings in highway construction. Lower fill heights are needed, bridge approach lengths are shortened, and successive levels of an interchange need less vertical separation. Grade HPS70W makes beneficial span depth to length ratios possible.

The availability of HPS coincides with heightened interest in rapid bridge construction. User delay costs are the most significant cost item related to bridge construction (*1*). Building bridges faster reduces user delay costs tremendously. Timely bridge construction can be achieved by reducing the amount of girders to erect. With HPS, the need for fewer girders to carry the load is realistic. The "get in, get out, and stay out" philosophy of rapid bridge construction also challenges bridge engineers to develop new bridge systems and methods of construction. J. Muller International has demonstrated an innovative way HPS can be employed advantageously in a method of rapid bridge construction for the state of Nebraska (*2*).

Parallel flange girders using HPS can be used advantageously for span lengths longer than 350 feet. Using parallel flange girders reduces fabrication and erection costs when compared to haunched girders. Using parallel flange girders also provides the opportunity to erect the girders by launching them from an end support. Although girder erection by launching is not used extensively in the United States, it could provide an option to steel erectors that would not otherwise be economically feasible with haunched girders.

However, all of these advantages come at a higher cost. Pound for pound, HPS is approximately 30 percent higher than Grade 50W steel (*3*). This price difference requires more than a 30 percent reduction in material, which is achievable with the higher strength of Grade HPS70W.

OVERVIEW OF HPS APPLICATION IN TEXAS

Precast, prestressed concrete girders, fabricated by a strong precast industry in Texas, have made it difficult for steel to be an economical selection for most bridges built in Texas. Nevertheless, the Texas Department of Transportation (TxDOT) is currently erecting about 10,000 tons of structural steel in bridges per year. The most common steel bridges currently being built by TxDOT are curved flyover ramps with spans between 200 feet and 350 feet. These structures have either four or five plate girders or two tub girders in the cross section. TxDOT also builds steel bridges for river crossings with span lengths in excess of 150 feet and for grade separation structures where vertical clearances cannot be achieved with concrete superstructures. Realizing the advantages HPS offers, TxDOT is beginning to use HPS in its steel bridges.

TxDOT is a proponent of the use of weathering steel in its bridges. Except in coastal regions or when painted girders are mandated by aesthetic considerations, TxDOT has long used weathering steel girders. With weathering characteristics better than conventional Grade 50W steel, HPS is an attractive material choice for TxDOT based on this consideration alone.

All of Texas falls within either AASHTO Temperature Zone 1 or 2 for toughness requirements. Even though HPS was developed for the more restrictive Zone 3, TxDOT still benefits from the higher toughness HPS provides. All steel bridges are susceptible to fatigue cracks. If any cracking were to occur in a structural element made of HPS, crack growth is expected to be much slower than with conventional steels, affording ample time to make repairs.

Until the advent of HPS, TxDOT discouraged the use of hybrid girder designs. For the past fifteen years, TxDOT typically used Grade 50 or 50W for all of its steel bridges. Because most TxDOT-built bridges are left unpainted, hybrid girders had not been an option. For painted bridges, TxDOT had not experienced a discernible cost benefit from designing hybrid girders with Grade 36 webs coupled with Grade 50 flanges. With the advent of Grade HPS70W, however, it has been shown that the most cost-effective use of this material is with hybrid girders (*3*). Grade HPS70W is expected to be economical for all bottom flanges and top flanges in negative bending. As a result, all of the bridges currently being built or designed by TxDOT with HPS utilize hybrid girder construction.

TxDOT provides field splices in girders at points of permanent load contraflexure. Other field splices are introduced as girder shipping lengths exceed approximately 130 feet. To economize, TxDOT policy is to allow steel erectors the option either to bolt or weld these splices. TxDOT is currently rewriting its field welding specifications to accommodate situations where Grade HPS70W material is encountered on both sides of a joint.

Examples of Texas Bridges Utilizing HPS

Connector I and Connector L, Nueces County

These bridges are both curved flyover ramps that are part of the interchange between State Highways 286 and 358, located in the city of Corpus Christi. Both bridges have a 40-foot wide roadway to accommodate two traffic lanes. Both bridges have curved portions. Connector I has an 811-foot radius, and Connector L has a 900-foot radius. Tangent portions of these bridges are framed with precast, prestressed concrete girders to maximize economy. The steel spans for Connector I are 190/230/190 feet. Connector L has two steel units. The first has span lengths of 190/190 feet, and the second has span lengths of 183/195.5/183 feet. All of the interior supports for these units are comprised of integral steel pier caps, necessitating bolted girder splices at each of these piers. See Figure 1 for a photo of an integral pier cap with bolted HPS flange splices.

The bridge site is approximately 16 miles from the Gulf of Mexico. The ability to use weathering steel was a concern due to the possibility of salt-laden air. An environmental analysis indicated that weathering steel would perform adequately, but the decision was made to paint the steel for aesthetic considerations. As a result, all of the non-HPS steel was Grade 50.

The *AASHTO Guide Specifications for Highway Bridge Fabrication with HPS70W Steel* (*4*) assumes HPS will be used in non-painted applications only. It may be advisable to change the *Guide Specifications* to address the welding of HPS to non-weathering steel.

HPS70W steel was used for both flanges in negative bending regions for some of the girders to eliminate the need for heavier Grade 50 flanges. The higher yield strength of HPS was the determining factor for its use in these bridges. The total amount of HPS70W steel used for these two bridges is approximately 80 tons. Only 2.75-inch and 1.5-inch HPS70W plate was used. No butt splices in the flanges had HPS on both sides of the splice. The girders are heat-curved. All of the web plates for these two bridges are 72 inches deep and use Grade 50 steel.

These bridges are currently under construction, and the girders were fabricated by Trinity Industries of Houston, Texas.

Southbound Loop 289 Direct Connector, Lubbock County

This bridge will be part of an freeway project in the city of Lubbock, Texas, and connects US 82 to Loop 289. The roadway width is 26 feet, and the slab thickness is 8.25 inches. The bridge has both tangent and curved portions, with a 1636-foot radius. Tangent portions are framed with precast, prestressed concrete U-beams, and the curved portion is framed with four steel plate girders spaced at 7.33-feet. There are two continuous steel girder units. The first has span lengths of 231.3/219.8/200.1 feet. The second has span lengths of 177.2/213.3/203.4 feet. The web plates are 78 inches deep and use Grade 50 steel. This bridge, like the preceding two in Nueces County, will have painted steel. Again, this is strictly an aesthetic consideration.

Grade HPS70W is applied for both flanges in the negative bending regions immediately over the piers and for some of the bottom flanges in the positive bending regions, resulting in hybrid girders. HPS prevented the need for much heavier Grade 50 flanges. Two thicknesses of HPS were used: 2-inch and 1.5-inch plate. TxDOT minimizes plate sizes when designing steel girders by limiting the different number of flange plates to four or six at the most. Even though two 1.5-inch flange plates may be used for a girder, if one is HPS and the other is conventional steel, the plates have to be considered as two different plates when considering this total. This practice, endorsed by fabricators, helps simplify the plate ordering process and reduces the number of full penetration welds.

This bridge has been designed, and construction may begin as early as 2003.

IH610 Northbound and Southbound Exit Ramps at US59, Harris County

These two bridges, located in Houston, Texas, are part of an interchange in Houston, Texas. The steel superstructures use trapezoidal steel box girders. Trapezoidal steel box girders have become common in Houston, primarily for their visual appeal. Both bridges are 26.42 feet wide and are supported by two girders each. The girders are 7.17 feet wide at the top of the webs. The webs are 79 inches deep and sloped at 1:4. The alignment for the Southbound Exit Ramp is curved with a 2864.8-foot radius, and the Northbound Exit Ramp is tangent. Span lengths for the Southbound structure are 200/270/270/200 feet, and span lengths for the Northbound structure are 195/270/270/195 feet.

At the piers bracketed by the 270-foot spans, Grade HPS70W was used for both the top and bottom flanges. Using HPS eliminated the need to introduce a flange width transition for the top flanges that would otherwise have been necessary if Grade 50W steel had been used. Fabricators discourage flange width transitions within a girder shipping length. Also, using HPS for these girders reduced their lifting weight, which is a more important issue with box girders than with plate girders.

The design for these bridges is complete, and construction should begin this year.

US59 Westbound Overpass at Spur 527, Harris County

This bridge, also located in Houston, Texas, has two 160-foot spans of curved steel plate girders. The pier between these two spans had to straddle a lower roadway. TxDOT often employs steel box girders as “straddle bents” in such situations. In this case, a box girder is needed and is simply supported by columns spaced 81 feet apart. The web plates are 78 inches deep and the flanges are 60 inches wide.

Grade HPS70W steel was used for both the top and bottom flanges in the regions of highest bending moment. The remainder of the steel is Grade 50W. The box girder is simply supported by columns spaced 81 feet apart. The web plates are 78 inches deep and the flanges are 5 feet wide. Again, using HPS avoided the need for much thicker and heavier flanges made of Grade 50W steel.

With the design complete, construction should begin on this bridge this year.

SUMMARY

TxDOT has used Grade HPS70W for straight and curved plate girders, straight and curved trapezoidal box girders, and substructure elements. With initial success implementing HPS in typical Texas bridges, it is expected that HPS will be a common component of steel bridges built by TxDOT in the future.

REFERENCES

1. Weissmann, J., and Harrison, R. Increasing Truck Size and Weight Regulations under NAFTA: The Bridge Dimension, *Journal of the Transportation Research Forum*, vol. 37, no. 1, pp. 1-14.
2. Price, K., Cassity, P., and Azizinamini, A. The Nebraska High Performance Steel Two-Box Girder System. Proceedings, 2001 World Steel Bridge Symposium, Chicago, IL.
3. Horton, R., Power, E., Van Ooyen, K., and Azizinamini, A. High Performance Steel Cost Comparison Study, *TRB 81st Annual Meeting Proceedings* (CD-ROM), 2002.
4. AASHTO Guide Specifications for Highway Bridge Fabrication with HPS70W Steel, September 2000.

LIST OF FIGURES

FIGURE 1 HPS flanges spliced at integral pier cap.